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The Influence of Late Treatment with Antibroadleaved Herbicides during Stem Elongation Stage of Durum Wheat on Sowing Characteristics of Seeds

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Abstract

The aim of this investigation was to establish the changes of sowing properties of durum wheat seeds and the quantity of waste grain due to the influence of 20 antibroadleaved herbicides, which were applied during the 1st, the 2nd, and the 3rd stem node stages of durum wheat. During the 1st stem node stage of durum wheat none of the herbicides included in the investigation had negative effect on sowing characteristics of durum wheat seeds. During the 2nd and the 3rd stem node stages of durum wheat herbicides such as Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat, and Akurat extra can be used in seed production crops of durum wheat. During the 1st stem node stage of durum wheat the antibroadleaved herbicides Arat, Biathlon, Derby super, Mustang, Weedmaster, Secator, Lintur, Akurat, Akurat extra, Eagle, Starane, Sanafen, Dicotex, and Herby can be used. These herbicides do not have negative influence on grain yield. During the 2nd stem node stage of durum wheat the herbicides Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat, Akurat extra, Starane, Dicotex, and Herby can be used. During the 3rd stem node stage of durum wheat only the herbicides Arat, Biathlon, Derby super, Secator, Lintur, Akurat, Akurat extra, and Starane can be used.

Key words: durum wheat, herbicides, late treatment, sowing characteristics, grain yield

Introduction

When using herbicides in practice, not only is it necessary to know the sensitivity of weeds to them but also their specific effect on wheat plants (Orlando, 1994; Kudsk and Streibig, 2003; Hassan et al., 2008; Shehzad et al., 2012). Compared to common wheat, durum wheat exhibits specific sensitivity to some herbicides (Rapparini et al., 2004; Campagna and Rueegg, 2006). There are data available in regards with the changes in the values of grain yield and grain quality (Baerg et al., 1996; Lobkov et al., 2012).

The treatment of seed production crops of durum wheat with herbicides is an important moment in the cultivation technology. We found from our previous studies that sowings seeds properties of different durum wheat cultivars have changed differently under the influence of some herbicides applied during tillering stage (Delchev, 2015). Sometimes in practice under the influence of various factors (meteorological, financial, organizational) herbicide campaign is delayed and crops are treated upon occurrence of stem elongation stage of durum wheat. The question of the influence of the herbicides applied on sowing properties of durum wheat seeds during this period has not been fully explored (Borojevic et al., 1990; Yenish and Young, 2000; Belanovskaya et al., 2006).

The aim of this investigation was to establish the changes in sowing properties of durum wheat seeds and the quantity of waste grain as a result of the influence of 20 antibroadleaved herbicides, which were applied during the 1st, the 2nd, and the 3rd stem node stages of durum wheat.

Materials and Methods

The research was conducted during 2012 - 2014 using a Bulgarian durum wheat cultivar Victoria (*Triticum durum* Desf. *var. valenciae*). A field experiment was carried out as a block method in 4 repetitions, on a 20 m^2 harvesting area, on pellic vertisol soil type, after sunflower predecessor. To explore the possibilities of coping with secondary weed infestation with broadleaved weeds in durum wheat fields for seed production, 20 antibroadleaved herbicides were investigated, namely Granstar 75 DF, Granstar super 50 SG, Ally max SG, Arat, Biathlon 4 D, Derby super WG, Mustang 306.25 SC, Weedmaster 646 CL, Sunsac, Secator OD, Logran 60 WG, Lintur 70 WG, Akurat 60 WG, Akurat extra WG, Eagle 75 DF, Herbaflex, Starane 250 EK, Sanafen, Dicotex 400, and Herby 675. The active substances and doses of the herbicides investigated are given in Table 1.

Tab. 1. The investigated herbicide variants

Испитиване варијанте хербицида

№	Herbicide	Active substance	Doses
1	Check	-	-
2	Granstar 75 DF	tribenuron-methyl	25 gha^{-1}
3	Granstar super 50 SG	tribenuron-methyl + tifensulfuron-methyl	40 gha^{-1}
4	Ally max SG	metsulfuron-methyl + tribenuron-methyl	35 gha^{-1}
5	Arat	tritosulfuron + dicamba	200 gha^{-1}
6	Biathlon 4 D	tritosulfuron + florasulam	55 gha^{-1}
7	Derby super WG	florasulam + aminopyralid	33 gha^{-1}
8	Mustang 306.25 SC	florasulam + 2.4-D	800 $mlha^{-1}$
9	Weedmaster 646 CL	2.4-D + dicamba	1 lha^{-1}
10	Sunsac	metosulam + 2.4-D	1 l ha^{-1}
11	Secator OD	iodosulfuron + amydosulfuron	100 $mlha^{-1}$
12	Logran 60 WG	triasulfuron	37.5 gha^{-1}
13	Lintur 70 WG	triasulfuron + dicamba	150 gha^{-1}
14	Akurat 60 WG	metsulfuron-methyl	10 gha^{-1}
15	Akurat extra WG	metsulfuron-methyl + tifensulfuron-methyl	50 gha^{-1}
16	Eagle 75 DF	chlorsulfuron	15 gha^{-1}
17	Herbaflex	beflubutamid + isoproturon	2 lha^{-1}
18	Starane 250 EK	fluroxypyr	1 lha^{-1}
19	Sanafen	2.4-D	2 lha^{-1}
20	Dicotex 400	2M-4X	4 lha^{-1}
21	Herby 675	2.4-D + 2M-4X	1.4 lha^{-1}

Weak adhesion by Granstar, Granstar super, and Ally max required their application with adjuvant Trend 90 - 0.1%. Weak adhesion of Arat and Biathlon required their application with adjuvant Dash HC –0.5lha^{-1}.

All herbicides were treated during the 1st, the 2nd, and the 3rd stem node stages of durum wheat. All variants were also applied with working solution of 200 l ha^{-1}.

To examine only the influence of herbicides and to eliminate the negative influence of weeds, they were removed by hand weeding during the growing period.

The grain gained after every variant was cleaned through a sieve with 2.2 mm holes and the quantity of waste grain was defined (siftings). Germination energy and lab seed germination were determined for all versions of sowing seeds. The intensity of early growth of seeds was studied, expressed by the length of primary roots and coleoptile definite on the eighth day after setting the samples. Each index was determined in two repetitions for each year. Mathematical data processing was done according to the method of one-way analysis of variance. To carry out the variance analysis, the ANOVA123 software was used for calculations.

Results and Discussion

The use of quality seeds is an important condition in order a normal crop and a good harvest could be obtained. Apart from high-yield, a cultivar which is resistant to diseases and pests must have necessary sowing properties, the main of which are high germination energy and seed germination. Germination energy is one of the most important characteristics of the sowing properties of the seed. Low germination energy leads to slower development of primary roots and coleoptile after seed germination and is associated with later germination in field conditions, lower tempering of plants and a higher risk of frost in winter. It leads to lower grain yields.

The results (Tables 1, 2, and 3) obtained in this study show that none of the investigated herbicides exerted influence on this index at treatment during the 1st stem node stage of durum wheat. Granstar, Granstar super, Ally max, Weedmaster, Logran, and Eagle lead to decrease in the germination energy of seeds at treatment during the 2nd stem node stage of durum wheat. At treatment during the 3rd stem node stage of durum wheat germination energy decreased not only due to the influence of these six herbicides, but also as a result of the influence of the Sunsac and Herbaflex herbicides.

Germination is the most important index which characterizes the sowing properties of the seed. At low laboratory germination sowing should be done with higher sowing rate, which increases the production costs. Laboratory seed germination including treatment during the 1st stem node stage of durum wheat at all variants is above the requirements of the standard for over 85% germination, although different years account for some variation of its values.

Tab. 2. Sowing characteristics of durum wheat seeds at treatment during the 1st stem node stage (2012 - 2014)

Сјетвене карактеристике сјемена дурум пшенице са третманом током фазе развоја првог нодија стабла

Herbicides	Germination energy, %	Seed germination, %	Length, cm		Waste grain, %	Grain yield	
			Coleoptile	Root		kg ha^{-1}	%
Check	96.0	99.0	11.56	18.01	7.8	5227	100
Granstar	91.0	96.6	10.03	18.09	8.1	4906	93.8
Granstar super	91.5	96.5	10.05	18.07	8.1	4916	94.0
Ally max	91.5	96.5	10.65	18.02	8.1	4926	94.2
Arat	96.5	98.0	10.85	18.06	8.0	5070	97.0
Biathlon	97.0	98.5	10.98	18.06	8.0	5036	96.4
Derby super	98.0	99.0	11.54	18.06	7.1	5185	99.2
Mustang	97.0	99.0	10.60	18.00	7.8	5061	96.8
Weedmaster	95.0	96.5	10.62	18.02	8.1	5102	97.6
Sunsac	95.5	98.0	11.50	18.18	8.1	4979	95.3
Secator	99.0	99.0	11.44	18.44	7.6	5208	99.6
Logran	95.0	96.0	11.09	17.96	8.3	4605***	88.1
Lintur	95.5	97.5	10.82	17.86	7.8	4939	94.5
Akurat	96.5	97.5	10.93	17.90	7.3	4978	95.2
Akurat extra	95.0	97.0	10.95	18.00	7.6	4977	95.2
Eagle	92.5	97.0	10.69	17.93	8.9	4984	95.3
Herbaflex	97.0	97.0	10.89	17.16	7.6	4832*	92.4
Starane	98.0	99.0	10.16	18.04	8.4	5125	98.0
Sanafen	96.0	97.0	10.20	18.03	7.8	4932	94.4
Dicotex	99.5	99.5	10.20	18.03	7.3	5058	96.8
Herby	98.5	98.0	10.20	18.03	7.6	5124	98.0
LSD 0.05	5.8	4.6	2.1	3.3	1.3	333	6.4
LSD 0.01	7.2	5.9	4.8	5.9	2.6	430	8.2
LSD 0.001	8.3	7.4	6.2	8.1	4.3	561	10.7

Marks *, ** and *** indicate significance at LSD 0.05, 0.01 and 0.001 significance level

It was shown that the Granstar, Granstar super, Ally max, Weedmaster, Logran, and Herbaflex herbicides decrease seed germination at treatment during the 2nd stem node stage of durum wheat – 5% to 9% decrease.

Tab. 3. Sowing characteristics of durum wheat seeds at treatment during the 2nd stem node stage (2012 - 2014)
Сјетвене карактеристике сјемена дурум пшенице са третманом током фазе развоја другог нодија стабла

Herbicides	Germination energy, %	Seed germination, %	Length, cm		Waste grain, %	Grain yield	
			Coleoptile	Root		kg ha^{-1}	%
Check	96.0	99.0	11.56	18.01	7.8	5227	100
Granstar	86.0***	91.0***	9.02*	16.08	10.8**	4806**	91.9
Granstar super	86.5***	92.0**	9.04*	16.06	10.6**	4834*	92.5
Ally max	86.5***	92.5**	9.64	16.00	10.6**	4828*	92.3
Arat	96.0	98.0	10.84	18.00	8.0	5039	96.4
Biathlon	96.5	98.5	10.97	18.07	8.0	4998	95.6
Derby super	97.0	99.0	11.53	18.05	7.8	5069	97.0
Mustang	96.5	98.0	10.58	18.08	7.9	4966	95.0
Weedmaster	87.0***	90.0***	9.61	16.50	11.9**	4750**	90.9
Sunsac	95.0	98.0	11.49	18.06	8.6	4979	95.3
Secator	98.0	98.5	11.42	18.05	8.5	5022	96.0
Logran	88.0*	92.0**	9.08*	16.90	8.6	4120***	78.8
Lintur	94.5	98.0	10.80	17.83	8.8	4926	94.2
Akurat	97.0	99.0	10.91	17.88	8.5	4944	94.1
Akurat extra	95.5	96.5	10.94	18.01	8.6	4932	94.4
Eagle	87.0***	96.0	9.68	16.90	11.9	4742**	90.7
Herbaflex	94.0	94.0*	10.88	17.17	8.8	4832*	92.4
Starane	97.0	99.0	10.17	18.03	10.3**	5038	96.4
Sanafen	95.5	96.5	10.19	18.04	9.1*	4787**	91.6
Dicotex	96.0	98.0	10.21	18.06	10.3**	4929	94.3
Herby	93.5	96.5	10.22	18.05	9.1*	4982	95.3
LSD 0.05	5.7	4.5	2.0	2.1	1.2	320	6.1
LSD 0.01	7.1	5.8	4.6	5.0	2.5	422	8.1
LSD 0.001	8.2	7.3	6.0	7.2	4.2	551	10.5

Marks *, ** and *** indicate significance at LSD 0.05, 0.01 and 0.001 significance level

Using the same herbicides during the 3rd stem node stage also decreases seed germination, but the negative effect is more intense - from 9% to 14%.

Tab. 4. Sowing characteristics of durum wheat seeds at treatment during the 3rd stem node stage (2012 – 2014)
Сјетвене карактеристике сјемена дурум пшенице са третманом током фазе развоја трећег нодија стабла

Herbicides	Germination energy, %	Seed germination, %	Length, cm		Waste grain, %	Grain yield	
			Coleoptile	Root		kg ha^{-1}	%
Check	96.0	99.0	11.56	18.01	7.8	5227	100
Granstar	78.0***	88.0***	8.83*	16.00*	11.2**	4634***	88.7
Granstar super	78.0***	89.5***	8.85*	16.01*	11.0**	4646***	88.9
Ally max	78.0***	89.5***	9.24*	16.00*	11.0**	4641***	88.8
Arat	96.0	98.0	10.80	18.06	8.9	4987	95.4
Biathlon	96.5	98.5	10.95	18.02	8.9	4945	94.6
Derby super	97.0	99.0	11.52	18.04	8.7	5003	95.7
Mustang	95.5	98.0	10.55	18.07	8.0	4915	94.0
Weedmaster	81.0***	86.0***	9.42*	16.39	14.1***	4564***	87.3
Sunsac	90.5*	98.0	11.46	18.02	9.4*	4630***	88.6
Secator	93.5	98.5	11.40	18.03	8.9	4982	95.3
Logran	95.0	96.0	9.08*	16.90	7.8	3702***	70.8
Lintur	95.5	97.5	10.78	17.82	8.8	4937	94.5
Akurat	96.5	97.5	10.90	17.86	8.8	4916	94.1
Akurat extra	95.0	97.0	10.93	18.00	8.7	4905	93.8
Eagle	86.5***	97.0	9.67	16.69	8.7	4687**	89.6
Herbaflex	93.0	93.0*	10.78	17.15	13.4***	4578***	87.6
Starane	98.0	99.0	10.16	18.02	11.6**	4941	94.5
Sanafen	96.0	97.0	10.17	18.03	12.7***	4678**	89.5
Dicotex	99.5	99.5	10.20	18.05	9.4*	4793**	91.7
Herby	98.5	98.0	10.20	18.04	12.8***	4817*	92.1
LSD 0.05	5.5	4.4	2.2	2.0	1.4	340	6.5
LSD 0.01	6.9	5.7	4.7	5.1	2.7	434	8.3
LSD 0.001	8.0	7.3	6.1	7.3	4.4	567	10.8

Marks *, ** and *** indicate significance at LSD 0.05, 0.01 and 0.001 significance level

This is a negative effect of their use, as it is necessary to increase the sowing rate (in kg ha^{-1}). This also increases the cost of necessary seeds and reduces the economic effects of durum wheat cultivation.

Although they decrease germination energy by treatment during the 3rd stem node stage, Sunsac and Eagle were not proved to have inhibitory effect on laboratory seed germination. Under the influence of these two herbicides seeds germinate normally, although their initial pace of development is weak due to weaker germination energy.

The results obtained for germination energy and seed germination are a prerequisite for continuation of the investigation on the effect of herbicides on initial intensity of the seeds growth, expressed by the root length. It was found that the length of coleoptiles of durum wheat decreased due to the effect of Granstar, Granstar super, Ally max, Weedmaster, Logran, and Eagle. This decrease was proved by the analysis of variants. These herbicides disable the development of young plants, reduce their resistance to cold and increase the risk of frost damages during winter months. Other herbicides do not have a negative effect on the growth of the primary roots and coleoptiles of durum wheat and can be recommended for the use in seed production crops of durum wheat.

When evaluating the sowing characteristics, we have to consider not only the characteristics of sowing seeds but also the quantity of waste grain (siftings) gained during the preparation of these seeds. Screening larger quantities leads to higher seed costs and reduces the economic effect of durum wheat seed production.

The results obtained show that none of the investigated herbicides at treatment during the 1st stem node stage of durum wheat cause change in the quantity of waste grain. Granstar, Granstar super, Ally max, Weedmaster, Eagle, Starane, Sanafen, Dicotex, and Herby at treatment during the 2nd and the 3rd stem node stages of durum wheat increase the quantity of waste grain. Sunsac and Herbaflex increase the quantity of waste grain only at treatment during the 3rd stem node stage of durum wheat.

Although Logran has high depressing influence on germination energy and laboratory germination of seeds, it does not increase the quantity of received screenings. On the other hand, Starane and similar three-hormone herbicides - Sanafen, Dicotex, and Herby increase waste grain quantity, although they do not influence germination energy and seed germination.

Arat, Biathlon, Derby super, Mustang, Secator, Akurat, Akurat extra, and Lintur lead to slight changes in the values of the investigated indices - germination energy, laboratory germination and quantity of waste grain which were not proved mathematically by using the analysis of variance.

Decreases in the values of germination energy and laboratory seed germination, changes in the intensity of the initial growth, expressed by the length of the root and coleoptile at germination, and changes in the quantity of waste grain influenced by the investigated herbicides are explained by depressing effects on the growth and development of durum wheat during its vegetative period.

In order to evaluate the sowing properties thoroughly, it is necessary to establish not only the quality of seeds, but also the quantity of grain that the seeds will yield. Data about the influence of the investigated antibroadleaved herbicides on grain yield showed that Arat, Biathlon, Derby super, Mustang, Weedmaster, Sunsac, Secator, Lintur, Akurat, Akurat extra, Eagle, Starane, Dicotex, and Herby applied during the 1st stem node stage of durum wheat did not affect the decrease of grain yield.

The Granstar, Granstar super, Ally max, and Weedmaster herbicides cannot be used during the stem elongation stage of durum wheat. During 2013 herbicides Granstar, Granstar super, and Ally max did not affect the decrease of grain yield. During 2013 the Weedmaster herbicide led to grain yield equal to the one from untreated control. This is due to different weather conditions in particular years. Also, Logran, Herbaflex, and Sanafen cannot be used during the 1st stem node stage because they have high phytotoxicity to durum wheat.

The effect of the Arat, Biathlon, Derby super, Mustang, Sunsac, Secator, Lintur, Akurat, Akurat extra, Starane, Dicotex, and Herby herbicides applied during the 2nd stem node stage of durum wheat was not proved to decrease grain yield.

With the advancement of stem elongation stage (from the 1st to the 2ndstem node stage), Granstar, Granstar super, Ally max, and Weedmaster enhanced their phytotoxicity with regard to durum wheat, which is especially strongly expressed by Weedmaster. It has been established that the selective action of the 2M-4X base herbicide (Dicotex) was better on durum wheat in comparison with the 2.4-D base (Sanafen). Owing to its lower content of 2.4-D and lower dose per hectare, the Herby herbicide also has better selectivity to durum wheat. From the 2nd stem node stage the Eagle herbicide had high phytotoxicity during each year of investigation.

Arat, Biathlon, Derby super, Secator, Lintur, Akurat, Akurat extra, and Starane applied during the 3rd stem node stage of durum wheat were not proved to decrease the grain yield.

The decrease of grain yield as a result of treatment with Granstar, Weedmaster, and Sunsac during the 3rd stem node stage was proved during each year, regardless of weather conditions. As for Granstar super, Ally max, and Mustang, the decrease of the yield was reported only during certain years.

Sanafen, Dicotex, Herby, Logran, Eagle, and Herbaflex also have a phytotoxic effect on durum wheat. The highest negative effect was shown by the Logran herbicide with the decrease of grain yield of up to 1525 $kgha^{-1}$ or 29.2 % in relative to the control.

Conclusions

During the 1st stem node stage of durum wheat none of the herbicides included in the investigation had negative effect on sowing characteristics of durum wheat seeds.

During the 2nd and the 3rd stem node stages of durum wheat in seed production crops of durum wheat Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat, and Akurat extra can be used. Regardless of the application period, these herbicides were not proved to influence germination energy, seed germination, the lengths of primary roots and coleoptile and also waste grain quantity of durum wheat.

During the 1st stem node stage of durum wheat the antibroadleaved herbicides Arat, Biathlon, Derby super, Mustang, Weedmaster, Secator, Lintur, Akurat, Akurat extra, Eagle, Starane, Sanafen, Dicotex, and Herby can be used. These herbicides do not have negative influence on grain yield.

During the 2nd stem node stage of durum wheat the Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat, Akurat extra, Starane, Dicotex, and Herby herbicides can be used.

During the 3rd stem node stage of durum wheat only the Arat, Biathlon, Derby super, Secator, Lintur, Akurat, Akurat extra, and Starane herbicides can be used.

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Утицај касног третмана хербицидима за широколисне биљне врсте у фази влатања дурум пшенице на сјетвене карактеристике сјемена

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Сажетак

Циљ овог истраживања је утврђивање промјена сјетвених карактеристика сјемена дурум пшенице и количине штурог зрна под утицајем 20 хербицида за широколисне биљне врсте, који су примјењени током фаза издуживања првог, другог и трећег нодија стабла дурум пшенице. У фази издуживања првог нодија стабла ниједан од испитиваних хербицида није имао негативан утицај на сјетвене карактеристике сјемена дурум пшенице. У фази издуживања другог и трећег нодија стабла, хербициди Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat и Akurat extra могу бити кориштени у усјеву сјеменске пшенице. У фази издуживања првог нодија стабла сљедећи хербициди за широколисне биљне врсте могу бити кориштени: Arat, Biathlon, Derby super, Mustang, Weedmaster, Secator, Lintur, Akurat, Akurat extra, Eagle, Starane, Sanafen, Dicotex и Herby. Ови хербициди немају негативан утицај на принос зрна. У фази издуживања другог нодија стабла сљедећи хербициди могу бити кориштени: Arat, Biathlon, Derby super, Mustang, Secator, Lintur, Akurat, Akurat extra, Starane, Dicotex и Herby а у фази издуживања трећег нодија стабла Arat, Biathlon, Derby super, Secator, Lintur, Akurat, Akurat extra и Starane.

Кључне ријечи: дурум пшеница, хербициди, касни третман, сјетвене карактеристике, принос зрна

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